Food-Energy-Water Literature Review

Compiled by Jen Schmidt

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Integration Questions:

1. What overlap among food, water, and energy have other publications found? If the null hypothesis is that there is no overlap, how do we show that is not the case?

Methods: Search for abstracts with food, water, and energy on web of science. Plus stuff Craig has sent me.

Food, water and energy:

(Hang et al. 2016;2017): Models were developed to develop process systems engineering tools combined with the concept of resource accounting using exergy for the design of such local production systems. They found overlap in using heat and power from natural gas to process water and the water is used to farm and raise cattle for local consumption. Wastewater generated from the food and energy subsystems could be treated in the water subsystem and organic waste from food subsystem could be used as a potential energy source for the energy subsystem.

(Al-Ansari et al. 2015) Integrated energy, water and food life cycle assessment tool that integrates FEW resources in one robust model. A case study set in Qatar and characterized by an agriculture sub-system.

(Lofman et al. 2002) provided a comprehensive review of the energy and water situation in the State of California and provided a series of policies that address the long-term uncertainties within the energy and water nexus for the State. They concluded that the nexus is highly skewed indicating that whilst energy production systems are weakly dependent on fresh water, the provision of fresh water (abstraction, production, distribution) is highly dependent on energy.

(Siddiqi and Anadon 2011) reviewed the energy and water sectoral characteristics for the Middle East. They concluded that the nexus is highly skewed indicating that whilst energy production systems are weakly dependent on fresh water, the provision of fresh water (abstraction, production, distribution) is highly dependent on energy, a relationship similar to that observed by (Lofman et al. 2002) in California.

(Ringler et al. 2013): Discusses Proactive engagement by the water, energy, land and food (WELF) sectors with important roles for national governments and international bodies is required to holistically assess and promote investment options that co-balance benefits across different sectors. Scarcity and efficiency has both helped and hindered conservation of resources.

(Hellegers et al. 2008) This paper sets the background and context of this special issue by highlighting some of the major water-related policy issues related to the subject and provides an overview and synthesis of the papers in this special issue.

(McCornick et al. 2008) Presents a case study of Ethiopia has an under-investment in water and energy infrastructure. They are trying to balance hydro with irrigation with food production.

(McCornick et al. 2008) In India the role of hydropower and diesel supply for groundwater withdrawal and policy issues such as energy supply and pricing add, therefore, another important dimension to the water–energy linkages in India. the major problem that affects both irrigation and hydropower relates to the long-term decline and temporal variation in the total water supply of the basin.

(Howells et al. 2013) This paper introduces the climate, land-use, energy, and water strategy. I gives numbers on energy and water needed for the the production of bio-fuels. Then has rainfall scenarios. Production of biofuels comes at the expanse of food production.

Water development for irrigation led to agricultural growth and power generation (Zilberman et al. 2008)

Biofuels also present new conflicts as their development can reallocate water, reduce food production affect the environment and create distributional problems (Zilberman et al. 2008)

(McCornick et al. 2008) In the Snake River Basin hydropower from dams and those on the Columbia River has provided inexpensive energy that has been the bedrock of the regional economy. Besides their power and irrigation contribution, the series of dams and locks have allowed barge traffic to reach Lewiston in Idaho, an inland port for agricultural products, primarily grain, nearly all of which are then exported.

(Food Agriculture Organization 2011, World Economic Forum 2011) Talks about trade-offs but mostly biofuels and water.

(Ferroukhi et al. 2015) Water used for crops, energy used to make water mostly in the Middle east. They also have a table the might be helpful:

	Water			Energy			Food		
	Access	Safe-ty	Afford-ability	Continuity of energy supply relative to demand	Physical availability of supply	Supply sufficient to satisfy demand at a given price	Physical availability of food	Economic and physical access to food	Food utilization
Water									
Energy									
Food									

Water and Energy:

(Eichelberger 2010): Dramatic increases in the costs of energy have led to decreased domestic water access, with adverse effects on household hygiene practices. Improving sanitation and access to domestic water requires considering the water–energy nexus: the amount and cost of energy required to treat and distribute water as well as manage waste.

(Eichelberger 2010): According to municipal financial statements, water and sewer systems are the single largest energy consumer in the Borough’s villages. Avoiding freeze-ups requires adequate heating fuel, glycol, heat tape, and electricity. Surging fuel prices have led to dramatically higher charges for electricity, which is produced locally through the use of diesel.

(Eichelberger 2010): Preventative maintenance during the summer requires gasoline, which is not only increasingly expensive (as much as $10 per gallon or more) but also often in short supply. Furthermore, operation and maintenance costs depend on the cost of freight, which has risen with the price of fuel.

(Eichelberger 2010): Hauling water or sewage requires a vehicle, usually a snow machine or a 4-wheeler.

(Eichelberger 2010): Soaring electricity and heating bills place a strain on household finances and deepen the situation of water insecurity.

(Eichelberger 2010): The primary reasons households abandon flush-haul systems are the associated electricity costs, poor cold weather design, and unpleasant smell.

(Eichelberger 2010): rising energy costs affect the social relationships of sharing involved in accessing water.

(Eichelberger 2010): residents in communities with self-haul systems have increasingly been faced with choosing between purchasing water or paying their household bills. The primary reasons households abandon flush-haul systems are the associated electricity costs,

(Eichelberger 2017): In Newtok the washeteria has been closed since 2000 due to insufficient funds for repairs and inadequate energy supply lines. the village's generator is inadequate for the amount of electricity needed to operate washers and dryers (Federal Emergency Management Agency (FEMA) 2015, interview data). Therefore, unlike many other remote Alaska Native villages, Newtok residents have no public showers, laundry, or flush toilets.

Moreover, hydropower today accounts for about 20 percent of total energy production and thermoelectric power plants account for around 40 percent of the freshwater withdrawn every year in Europe and the United States (Kenny et al. 2009, Rübbelke and Vögele 2011).

(Irabien and Darton 2016) For tomato production in Spain water and energy supply play the mean role with a trade-off between the water quality degradation and the economic cost of the energy for water desalination.

More global but The Climate Land-use Energy and Water Strategies (CLEWS) framework, integrating three separate subsystem models (Howells et al. 2013). Energy for water processing, treatment, desalination, hydropower, power plant cooling.

Energy and water usage (van Vliet et al. 2012, Miara et al. 2013) Van Vliet is a great model study on the link between water and energy production in the developed world.

(McCornick et al. 2008) Jordan water is extremely scarce and energy use is intensive. Energy is needed for lifting, moving and treating surface water, especially from the Jordan Valley.

(Ferroukhi et al. 2015) Provides the amount of energy needed to treat various types of water for human consumption.

Energy and food:

(Saylor and Haley 2007) Across the region, energy costs continue to affect many aspects of village life, from the price of food to utility bills, which consume as much as 33% of household incomes.

Price of fuel relates to price of food (ICC Canada 2012, Ringler et al. 2013, Keairns et al. 2016)

Almost 70 percent of people in Sub-Saharan Africa continue to rely on **wood and by-products as their primary cooking fuel** (Legros et al. 2009)

(Food Agriculture Organization 2011) People in poorer countries use more energy to prepare and cook food than higher income countries. This has energy expenditures for different kinds of meat and food. Also the range of different renewable energy types and comparison with typical gas, diesel, and electricity costs.

(Food Agriculture Organization 2011, Howells et al. 2013) Energy and biofuels. Energy is also needed to produce fertilizer and to prepare land, harvest crops, and dry and process agricultural produce.

Fuel costs are a significant factor in the expenses for the halibut and sablefish commercial fisheries. Over 60% of respondents in the Aleutians reported that fuel costs were 16% or more of their total costs (Kotlarov 2015).

(Ferroukhi et al. 2015) Overview of the amount of energy it takes to globally produce foods and different types of foods.

Food and water:

Water and cooking food/washing dishes: tested for but they didn't show data as to how often this occurred (Hadley and Wutich 2009).

The Food and Agriculture Organization (FAO) points out that in the past 50 years agricultural production has grown between 2.5 and 3 times, whereas the cultivated area has grown by only 12%. But as a consequence, agriculture now accounts for 70% of all water withdrawn from aquifers, streams, and lakes.

Global annual groundwater withdrawals are large and increasing, accounting for 43 percent or more of global irrigation use (Siebert et al. 2010), in large part due to the availability of smaller, cheaper pump sets and tubewell technology (Shah 2007).

(Howells et al. 2013) Agriculture alone accounts for 70% of global water withdrawals and industry for another 22%, most of which is for cooling thermal processes in power generation and manufacturing5.

A report recently released by the Inuit Circumpolar Council highlights water as an integral part of food security for indigenous populations in the Arctic (ICC 2015).

2. What have others found important for FEW security, especially among remote, rural communities?

Food Security articles:

(Loring et al. 2013): In this paper we explore the relationship between food security and access to locally caught seafood for communities of the Kenai Peninsula region of Alaska. With data collected via a by-mail survey, we show that many people in our Alaskan study region enjoy **improved food security because they have access to locally caught seafood**, especially those households at the lowest income levels.

(Smith et al. 2008): With interviews, dietary recall, and block brief food frequency tool showed that (64% Alaska Native) indicated positive dietary and lifestyle habits. Food insecurity reported by 39% rural and 7% of urban. Hunger was reported by 16% of rural and 5% of urban women. More research is needed to understand the high rates of food insecurity and hunger reported in rural Alaskan communities when mean nutrient intakes appear adequate**. The levels of reported food insecurity in Alaska's urban areas may reflect the family's limited access to traditional food sharing networks, as well as limitations of cash income needed to purchase foods**. One third of calories came from non-traditional sugared and fruit juice beverages.

REVIEW ARTICLE: (Walch et al. 2018): A review article of food security in Alaska. Pillars of food security are availability, utilization, and access. Says that the (Loring et al. 2013) and (Smith et al. 2008) papers are the only ones that really look at food security. Others quantify traditional food intake (n=18) and qualitative address one pillar of food security (n=8). Factors that appear to influence traditional food availability and access include climate change, food sharing, living in urban areas, costs associated with following a traditional lifestyle and changing food preferences.

(ICC 2015, BurnSilver et al. 2016, Kofinas et al. 2016): Community patterns differ with respect to the extent of the resilience and sustainability of traditional foodways, including the role of a **mixed cash and subsistence economy**, and **whether all people's cultural, spiritual and nutritive needs are being met through the current traditional food system**.

Climate change (Brubaker et al. 2011, Flint et al. 2011, ICC Canada 2012) impacts food security. Climate change ranging from a rise in sea levels from melting ice caps and glaciers to thawing permafrost and changing weather and winds.

Concerns about **contamination** in the traditional food supply (Flint et al. 2011, ICC Canada 2012)

(Loring and Gerlach 2010, McNeeley and Shulski 2011) **Changing wildlife migration patterns**
high equipment and fuel prices (Chan et al. 2006, Fazzino and Loring 2009, Magdanz et al. 2011)

Economic vulnerability and income (Hadley and Wutich 2009, ICC Canada 2012)

loss of traditional knowledge (Flint et al. 2011)

Food availability and access, **such as differing species or hunting locations, changing animal migration patterns** (Guyot et al. 2006) and **regulations on wildlife management** (Goldhar et al. 2010).

The Arctic Food Security & Nutrition Network examines policies, nutrition, economics, and social/cultural influences on food security. (Wayne Unk)

Geography, ethnicity, and remoteness are associated with lower food security (i.e. need for and use of SNAP services) (AKDHSS and UAF 2014)

Dependence on store food (Kuhnlein and Receveur 1996, ICC Canada 2012)

Extreme weather (ICC Canada 2012)

Ability to access and select nutritious market food is increasingly dependent on the ability to pay (Kuhnlein and Receveur 1996, Chan et al. 2006, Chabot 2008, Loring and Gerlach 2009, FBC 2012)

Season (Hadley and Wutich 2009)

Gender (Hadley and Wutich 2009)

Growing food (Hadley and Wutich 2009)

Water Security:

Infrastructure (Hennessy et al. 2008) An estimated one third of Alaska Native village **households lack running water** (Hennessy et al. 2008), and the ones that do have running water face periodic shortages because of **Frozen pipes** (Hennessy et al. 2008).

Inability to pay for services (Hennessy et al. 2008)

Poor availability of water treatment plant (Eichelberger 2010, Eichelberger 2017)

Lack of boat or vehicle (Eichelberger 2017)

Social networks (Hadley and Wutich 2009, Eichelberger 2017)

Gender (Hadley and Wutich 2009)

Season (Hadley and Wutich 2009)

Income (Hadley and Wutich 2009)

Storage capabilities (Hadley and Wutich 2009)

3. Can FEW security be made better? If so, how?

(Academies 2014) The lack of a comprehensive review of northern food security derived from the first-hand experience and knowledge of northern peoples is a major knowledge gap identified by the Panel.

In Canada (ICC Canada 2012): Nutrition and food choice, environmental health, environmental change, identifying the resource limits of country food products, calculating how much money communities could save by increasing local food supplies and decreasing reliance on imported food. , investigating how Hunter Support Programs could be expanded, determining employment and income benefits from country food stores, determining the extent to which the ability to sell country food could enable harvesters to continue with their chosen form of livelihood; and extent to which food sharing mitigates food insecurity.

(Voulvoulis 2012) Water reclaiming technology

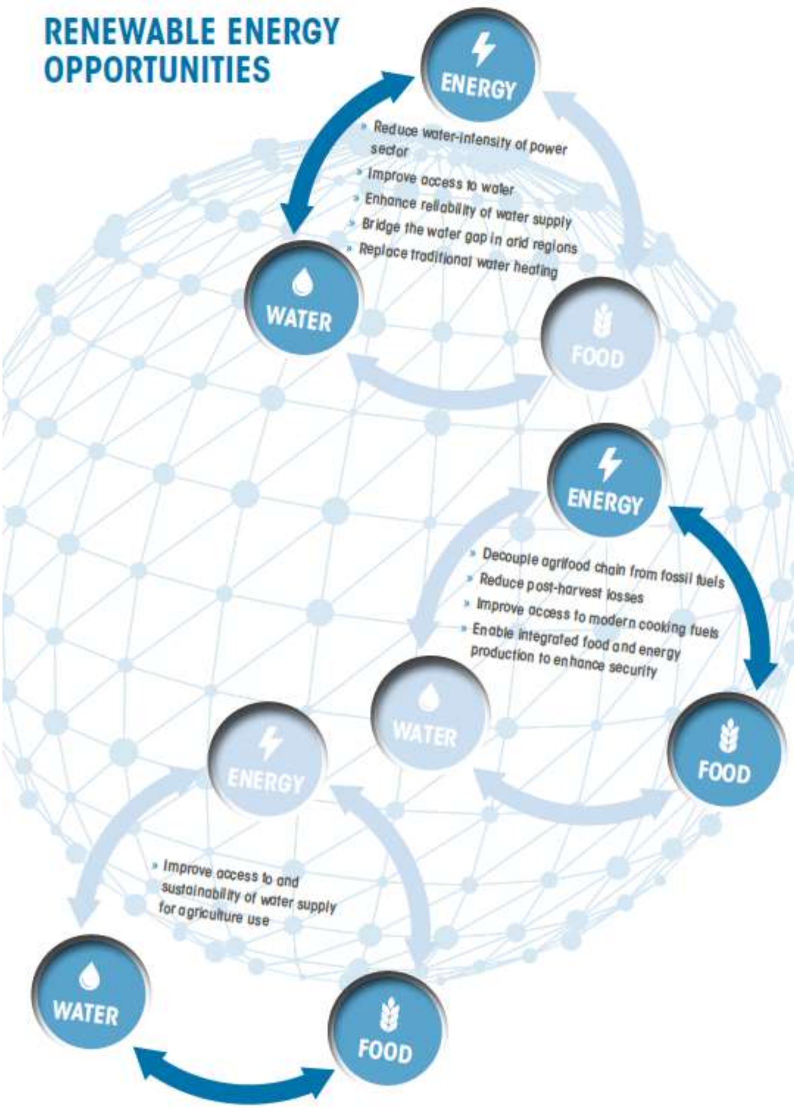
(Wong and Pecora 2015) Energy technology to address water scarcity

(ICC Canada 2012) More stable economy, jobs, lower fuel costs

4. What has been the influence of renewable energy on communities, especially among remote, rural communities?

If the null hypothesis is that renewable energy has no influence on communities, then how do we show this is not the case? This question feeds into the work we are doing right now outlined by Erin and one of our group phone meetings.

(Ferroukhi et al. 2015) Below is how renewable energy might help.



5. Use the nexus synthesis paper as a starting point to examine which nexus approaches might be useful for our project either directly or as a guide.

Nexus methods

(Loulou 2007) Review of 8 main methods below. Of them 2 (Mohtar and Daher 2013) and 5(FOA nexus) seem the most usable

Climate, Land-use, Energy, and Water (CLEW) (Alfstad, 2013)	• Extensive data requirements • Technical and economic parameters of power plants, farming machinery, water supply chain, desalination terminals, irrigation technologies, fertiliser production, etc.
The Water, Energy, Food Nexus Tool 2.0 (Mohtar and Daher, 2013)	• Data and local characteristics of food, water and energy systems • Local production of food, water and energy (per type) • Context-specific policy inputs
MARKAL/TIMES (Loulou et al. 2005)	• Extensive data requirements • Techno-economic details of energy technologies • Characterisation of the reference energy system
WEAP-LEAP (SEI, 2013)	• Extensive data requirement • Techno-economic details of energy technologies
FAO's nexus assessment methodology (FAO, 2014)	• Indicators that are already available • Key classifications of the country under study to place it under country typologies
WBCSD Nexus tool (WBCSD, 2014)	• Characterisation of the energy sector • GIS maps and information • Characterisation of water for food and for energy • Information on labour force and availability of machinery
MuSIASEM -The Flow-Fund Model (FAO, 2013)	• Extensive data requirements • Socio-economic indicators, including work force evolution • Availability of land • Climate change impacts • Characterisation of all flows
Diagnostic, Financial, and Institutional Tool for Investment in Water for Agriculture (Salman, 2013)	• Full data sets needed to characterise local irrigation and hydropower projects

(Irabien and Darton 2016): Process Systems Analysis Method (Craig sent me stuff) connects the ecosystem services to the market demands with a holistic view based on Life Cycle Assessment. **Process analysis method (PAM)** proposed by Chee Tahir and Darton (2010). In this method, the system under study is described as a set of processes that produce impacts. The objective is to design a sustainable supply/demand balance considering the evolution of the economic, social and environmental stores of capital. The PAM was used to look at tomato E-W-F in the tomato production in Almeria (Spain). I was developed as an example of the food production under cropland restrictions, semiarid land. The application of the carbon footprint, water footprint and chemical footprint as indicators allows a quantitative assessment for the system. **Food Resource (KcalF/m2-time) being KcalF the human chemical energy supplied by the food, Water Resource water supply (m3/time m2) and Energy**

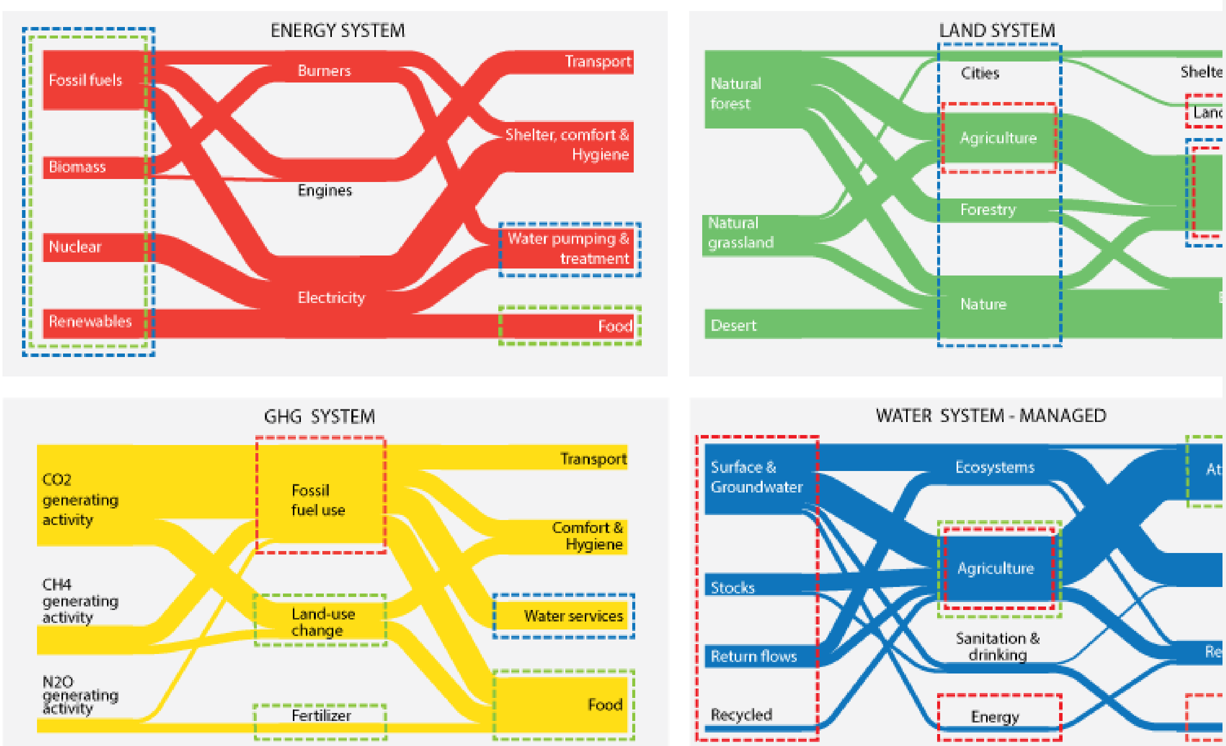
Resource (KJ/m2 time). The system must facilitate adaptive actions based on decisions of the Institutional Agents, Market Agents and other stakeholders leading to greater sustainability. The first step is the creation of a descriptive model of the system that includes all the processes that cause relevant impacts. We identify the three main scales as the global scale (planet), the regional scale (based on political and social agreement) and the local scale. The relationship among scales is based on regulations, on trade agreements and/or on market and consumers decisions, using transport and information technologies to connect the scales.

Life Cycle Assessment have been recommended for the energy-water food nexus (Al-Ansari et al. 2015). LCA has developed quickly over the past three decades (Guinee et al. 2011). From its early beginnings in energy, resource, and waste accounting, LCA emerged as a rigorous methodology for environmental burden analysis in the 1970s. Efforts continue with the aim of extending the LCA concept to social impacts (SLCA). Examples include: breakfast cereals and snacks (Jeswani et al. 2015) and in bananas (Roibás et al. 2015). The production of biofuels from energy crops has often been analyzed with LCA (Pacetti et al. 2015). Murphy & Allen (Murphy and Allen 2011) underlined the need for a comprehensive analysis, using the process engineering tools of energy and mass balance to show that in manufacturing a particular algal biodiesel.

Sankey diagrams to help visualize the nexus https://www.foreseer.group.cam.ac.uk/

The Foreseer tool has been developed for California, and is currently being developed for China and the United Kingdom.

Below is a schematic that demonstrates how water, energy, land are connected. For example, water is needed for the extraction of fossil fuels, whilst energy is needed for the distribution and treatment of water.



Below Figure recognizes the central role of stakeholder dialogue in finding solutions and "managing the Nexus," (FOA 2014)

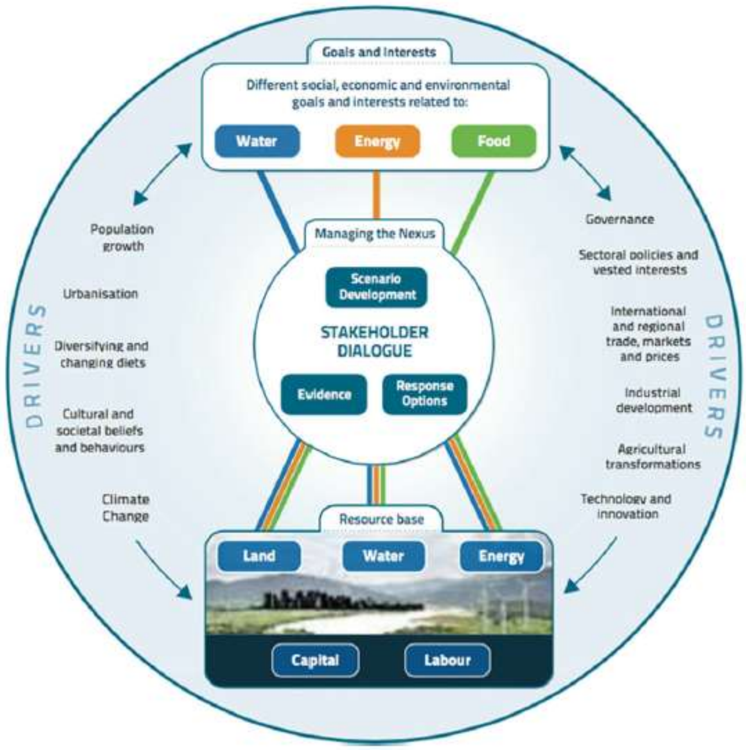
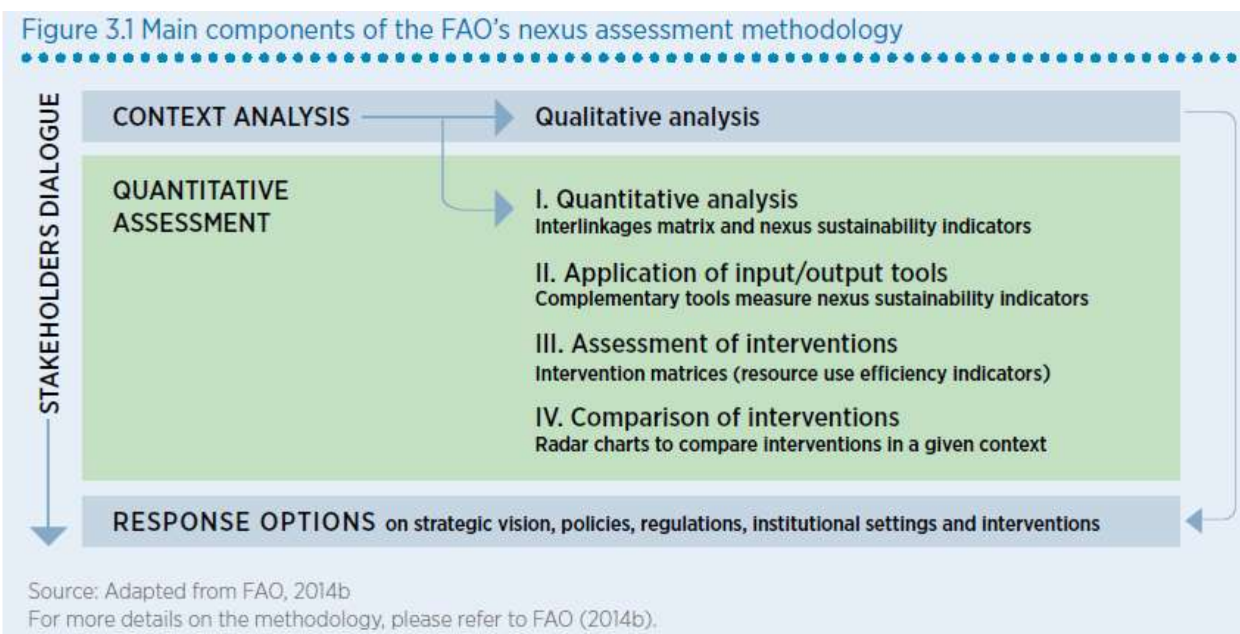


Fig. 1 FAO view of the E–W–F nexus (FAO 2014)

FOA has an assessment mythology.



Shell New **Lens Scenario** (Global 2013) evaluates energy future choices within the context of their "stress Nexus" characterization and a focus on the need for collaboration between companies, governments, and civil society.

(Liu et al. 2015) advocate using existing and well-researched concepts to construct integrated solutions to Nexus challenges. He also advocates for **telecoupling** (socioeconomic and environmental interactions over distances to tie distant places together (Liu et al. 2013)

(Ferroukhi et al. 2015) surveys of Energy-Water-Food Nexus modelling tools.

WELMM, model developed at the International Institute for Applied Systems Analysis, IIASA (Grenon and Lapillonne 1976). The WELMM model was designed to estimate the requirements for these five "limited" resources in developing energy resources.

MESSAGE (Model for Energy Supply Systems and their General Environmental impact) framework for modelling potential future energy scenarios (IIASA 2015). MESSAGE is a dynamic linear programming model minimizing total costs of energy supply over a given time horizon. Scenarios developed with MESSAGE have been used in, for example, the assessments and special reports of the IPCC and the GEA. Again, this seems like more a global model.

MuSIASEM (Multi-Scale Integrated Assessment of Society and Ecosystem Metabolism) approach is based on concepts from bioeconomics and complex systems theory; it can be used as a tool to characterize patterns of an existing socioeconomic system or to check the self-consistency and implications of a scenario. MuSIASEM, originally developed for an energy economy, has been extended to the Nexus by including food and water in its accounting methodology (LIPHE 2013). Again, this seems like more a global model.

Stockholm Environment Institute (SEI) has developed the **Water Evaluation and Planning (WEAP) system**, a software tool that helps to balance competing demands for fresh water in a particular geography (Yates et al. 2005).

Mohtar, Bassel T. Daher developed the **WEF Nexus tool** during pursuing his MSE degree at Purdue University. The interface was later created at Qatar Environment and Energy Research Institute and the first tool version was launched October 2013 and was publicly available on the QEERI website. http://www.wefnexustool.org/about.php The first tool version was accessed by users from more than 20 countries, coming from more than 50 institutions and governmental agencies worldwide.

(Loulou 2007) MARKAL/TIMES food water energy economic modeling approach but again seems largely for agriculture.

Climate Land-use Energy and Water Strategies (CLEWS) modelling framework (Bazilian et al. 2011, Howells et al. 2013) is simple. Land, energy, and water resource systems are highly integrated and so must be treated as such. An example of the CLEWS framework, integrating SEI's LEAP [Long-range Energy Alternatives Planning tool (http://www.energycommunity.org/LEAP/)]

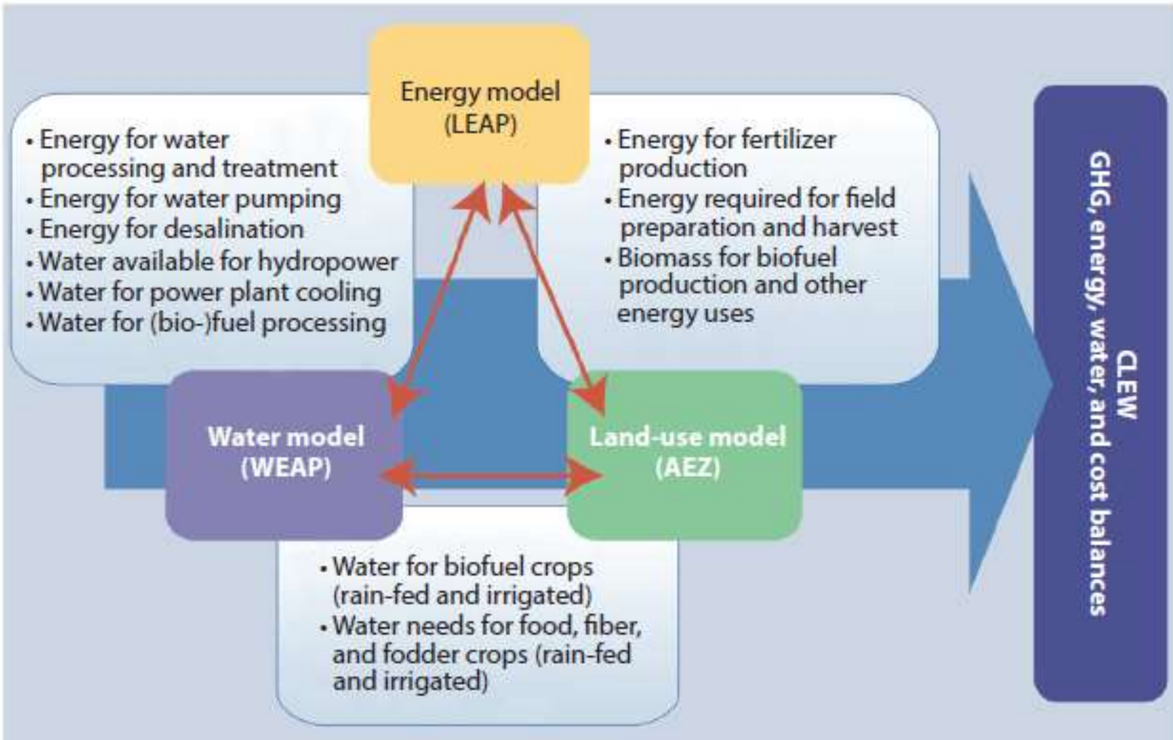
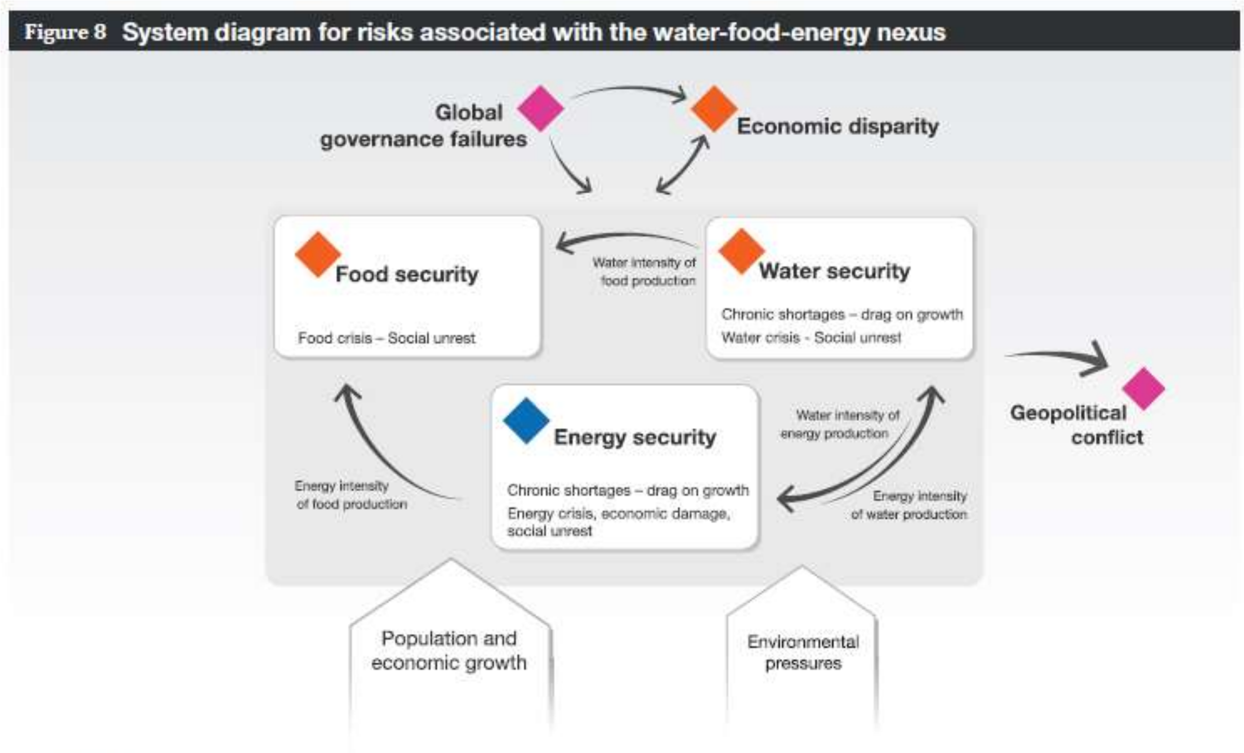


Figure 8

The Climate Land-use Energy and Water Strategies (CLEWS) framework, integrating three separate subsystem models (33). Abbreviations: AEZ, Agro-Ecological Zoning; GHG, greenhouse gas; LEAP, Long-range Energy Alternatives Planning tool; WEAP, Water Evaluation and Planning.

(World Economic Forum 2011)



Source: World Economic Forum

A global modelling solution is also derived by the **IMAGE framework** described by (Bouwman et al. 2006). IMAGE, an Integrated Model to Assess the Global Environment, includes several modules to calculate various Nexus subsystems, including energy, land use, food and water provision, and biodiversity. This looks global and would be hard to do for Alaska or communities.

Below figure (Hoff 2011). The guiding principles included investing to sustain ecosystem services, creating more with less, accelerating access, and integrating the poorest in society. This paper is one of many that has viewed the provision of the three basic commodities through the lens of “security.” Hoff uses are based on (affordable) access to safe drinking water and sanitation; clean, reliable energy services; and sufficient, safe, and nutritious food.

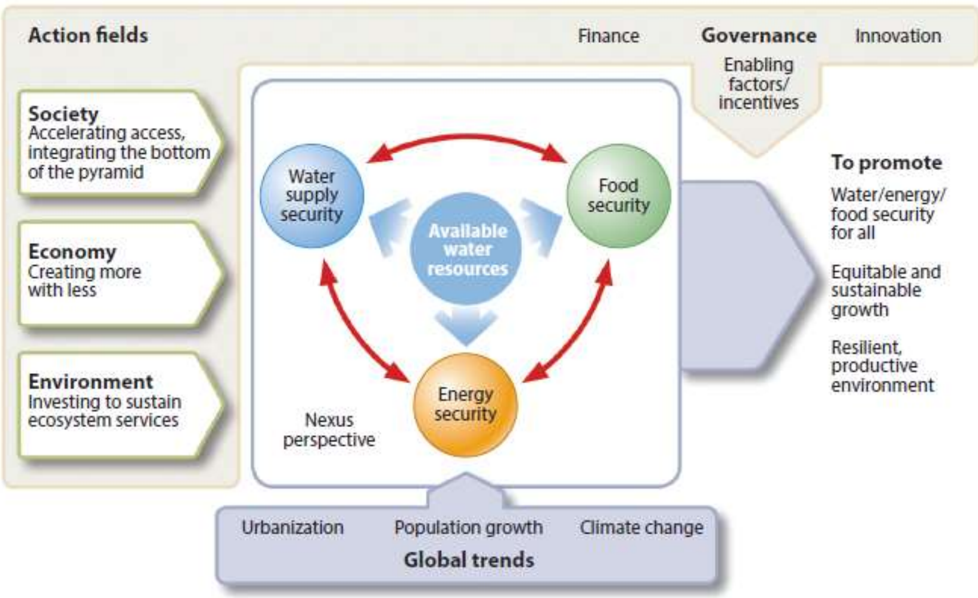
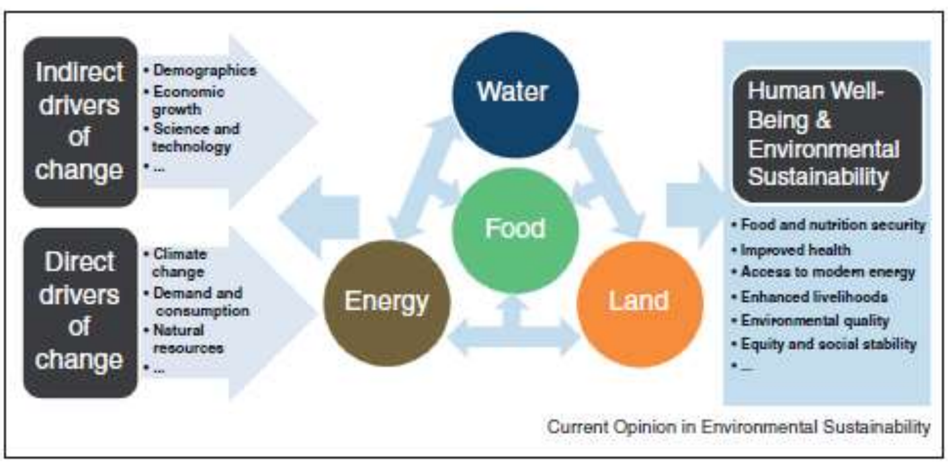


Figure 2

The water, energy, and food security Nexus (19).

Below figure (Ringler et al. 2013)

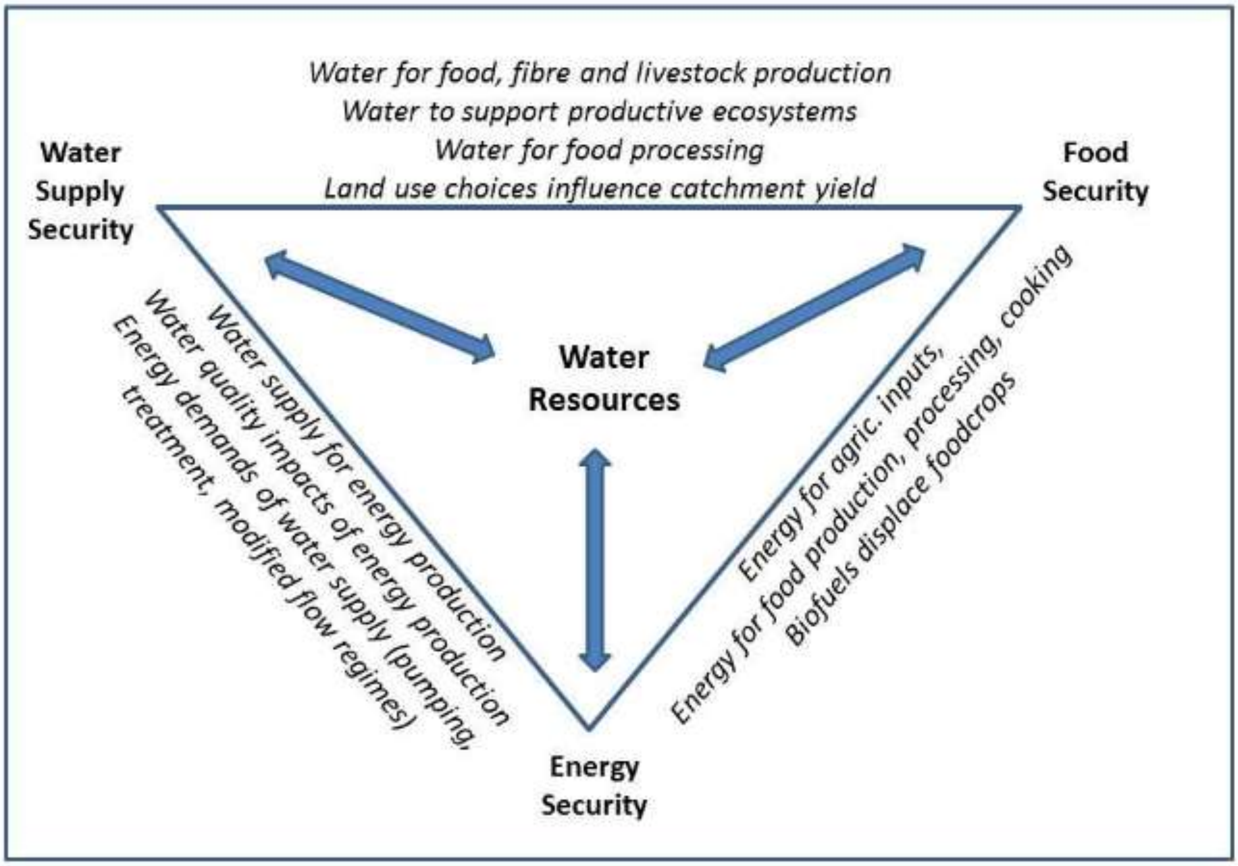
Figure 3



Extended water, land, energy and food nexus framework

OVERALL: This seems like it might be hard to do for rural Alaska getting the water, food, and energy numbers would be really hard.

Below figure is from (World Water Forum 6 2012)



Assessing Food Security

Surveys:
(Sharma et al. 2008, Smith et al. 2008, Huet et al. 2017)Some work has been done to estimate the prevalence and severity of food insecurity and blend the USDA Food Security Survey Module with methods that capture traditional foods. These kinds of surveys with other approaches to dietary recall in Alaska and elsewhere.

(Kostick Unk) Inserts questions about how Supplemental Nutrition Assistance Program (SNAP) is used by rural Alaska residents for subsistence.

(ICC 2015): Inuit Circumpolar Council has produced a new framework for evaluating traditional food security.

(Hadley and Wutich 2009) Survey questions to assess food and water security in Tanzania and Bolivia.

USDA Household Food Security Module (Hadley and Wutich 2009).

This paper suggests metrics for food and water security. Maybe data could be gathered to see if there is a relationship. (Nilsson et al. 2013).

Assessing Water Security

Assess: water quality, quantity or adequacy, source or reliability, and affordability—have subsequently been included in most definitions of HWI

Interviews:
(Eichelberger 2010, Eichelberger 2014, Eichelberger 2017)

Survey/Questionnaire:
Guttman methods (Hadley and Wutich 2009)

Qualitative and quantitative methods

Entitlements and human capabilities (Wutich and Brewis 2014, Jepson et al. 2017)

Socio-cultural dynamics (Eichelberger 2010, Eichelberger 2014, Eichelberger 2017)

Political institutions and processes that produce water related inequities (Jepson et al. 2017).

Risk (Garrick and Hall 2014)

Rights (Bustamante et al. 2012)

Environmental sustainability and adaptation (Vörösmarty et al. 2010, Scott et al. 2013)

Water quality (Christina 2016)

Complexity and policy (Zeitoun et al. 2016)

Hydro-social cycle describes ''the process by which alterations or manipulation of water flows and quality affect social relations and structure, which, in turn, affect further alteration of water" – its flow, processes and movements (Linton and Budds 2014, Jepson et al. 2017)

Other interesting connections:
Water security was linked to missing school (Cooper-Vince et al. 2017)

Internationally, the United Nations Development Program defines affordable water as that which costs no more than 3–5% of a household's income (Hutton)

REVIEW ARTICLE: (Keairns et al. 2016)

Ringler et al. (Ringler et al. 2013) present six recommendations for reducing the ambiguity of trade-offs. It is mostly global thoughts.

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